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LMSC/D458860

Oceanographic Noise Measurement Test at the Santa Cruz Acoustic Range Facility

Final 5-7-75 to 10-22-75

D. J. Edelblute

N00014-75-C-0386

Lockheed Missiles & Space Company, Inc.
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Item 0002

Office of Naval Research
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None

Comparative noise measurement tests, DELTA Array, Santa Cruz Acoustic Range Facility, low frequency noise data, parachute mooring and tensioning system.

This report documents comparative ocean noise measurement test data taken simultaneously from a deployed horizontal passive array and a fixed vertical line array. The frequency regime of interest on these tests is below 20 Hz.

LMSC/D458860

~~FINAL REPORT ON~~ OCEANOGRAPHIC
MEASUREMENT SYSTEM TEST AT SANTA CRUZ
ACOUSTIC RANGE FACILITY (SCARF)

15 October 1975

This project was sponsored by the Office
of Naval Research under the provisions
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~~requisition number~~)

Prepared by: Date: 15 Oct 75
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Approved by: T. J. Anderson Date: 15 Oct 1975
T. J. Anderson
Director, Program Development

LOCKHEED MISSILES & SPACE COMPANY, INC.

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FINAL REPORT ON OCEANOGRAPHIC MEASUREMENT SYSTEM TEST AT SANTA CRUZ ACOUSTIC RANGE FACILITY (SCARF)

I INTRODUCTION

The DELTA hydrophone array, developed by LMSC, was acoustically tested on the Santa Cruz Acoustic Range Facility (SCARF), operated by Delco Electronics on 6 August 1975. The purpose of the test was to verify the acoustic performance of the DELTA array in the low frequency region ($<$ 20 Hz). While the array was deployed on the SCARF range, recordings were made of voltages from the DELTA hydrophones and the SCARF noise measurement hydrophones.

Spectra of these voltages showed the DELTA sensors to be 5 to 10 dB quieter than the SCARF sensors in the 5 Hz to 20 Hz region. The two systems showed comparable levels in the 20 Hz to 50 Hz region. Above 50 Hz the DELTA sensors were considerably noisier than the SCARF sensors. This noise probably came from the test ship, R/V SWAN, which was much closer to the DELTA sensors than the SCARF sensors.

The data appeared about as would have been expected.

II TECHNICAL BACKGROUND AND PURPOSE

The unique suspension system of the DELTA array was developed to reduce array self noise. The lower in frequency one tries to work, the more difficult self noise is to control. Therefore tests of the low frequency noise from the DELTA sensors are of paramount interest to determine how successful the DELTA design is.

A test on the SCARF range was planned to measure the low frequency noise from DELTA. The SCARF sensors, being mounted in a more conventional way,

were to provide data for a comparative analysis.

The SCARF range is in many ways well adapted to such a task. It can track a ship so that the geometry of a test is accurately known. The noise measurement string provides well calibrated measurement of noise levels at 200 ft, 400 ft, 600 ft, and 1000 ft depths.

There were two difficulties in the use of the SCARF range.

First, the SCARF sensors were intended for use at frequencies above the frequencies of principal interest (below 20 Hz). Accurate calibration data exists only at 20 Hz and above. The calibration values below 20 Hz are necessarily extrapolations. These extrapolations provided by Delco Electronics appear to be adequate and are the only data available for a valid test.

Second, the ocean currents on the SCARF range are unpredictable and change frequently, both in velocity and direction. To insure that the DELTA array did not drift into the noise measurement string, it was necessary to deploy the array about 3 NM from the measurement string and to station the R/V SWAN close to DELTA. At frequencies above 50 Hz the noise from the R/V SWAN appears in the DELTA sensor voltages much stronger than the SCARF sensor voltages. This obscures direct comparison between DELTA and SCARF at those frequencies. However, at the frequencies of principal interest, the R/V SWAN noise is greatly reduced due to its small size and proximity to the ocean surface. Thus, below 20 Hz a valid test is possible.

The DELTA system has low self noise characteristics at the very low frequencies because the parachute suspension system essentially moors the hydrophones to the water mass at the same depth as the hydrophones.

Figure 2-1, "DELTA NOISE TESTS" shows the significant features of the parachute mooring and tensioning system.

On the right side of Figure 2-1 a surface buoy supports a 500 ft long riser line which is attached to the crown of a parachute. A 10 pound lead weight is attached to the crown of the parachute for depth control.

A 100 ft long rubber line is the tension leader between the parachute shroud lines and the 400 ft long hydrophone section. A surface isolation module (SIM), which entraps 500 pounds of sea water inside its aluminum surface, is attached to the other end of the hydrophone section.

A 200 ft long rubber line is the tension leader between the SIM and the 50 pound lead weight at the bottom of the cable to the data buoy. An instrumentation skiff is moored to the data buoy. A light braided nylon line about 3,200 ft long is the tension line. This line is attached to the 50 pound weight at the bottom of the cable and passes through the pulley block to a 50 pound lead weight.

The shroud lines of the tension parachute are attached to the pulley which supports the lead weight. The crown of the tension parachute is attached to a 500 ft long riser line to a surface buoy. As the 50 pound lead weight falls, it pulls the two parachutes towards each other. It takes about 2 hours and 40 minutes for the weight to pull the 3,200 foot tension line through the pulley.

The rubber tension leader lines and the mass of the surface isolation module effectively isolate the hydrophone section from wave action and other mechanical disturbances.

The lightweight deployable DELTA system does not have the self calibration features of the SCARF range. The array electronics received a bench calibration both before and after the SCARF test. In addition the spectrum levels of the four hydrophones were less than 1 dB apart on spectral lines

DELTA NOISE TESTS

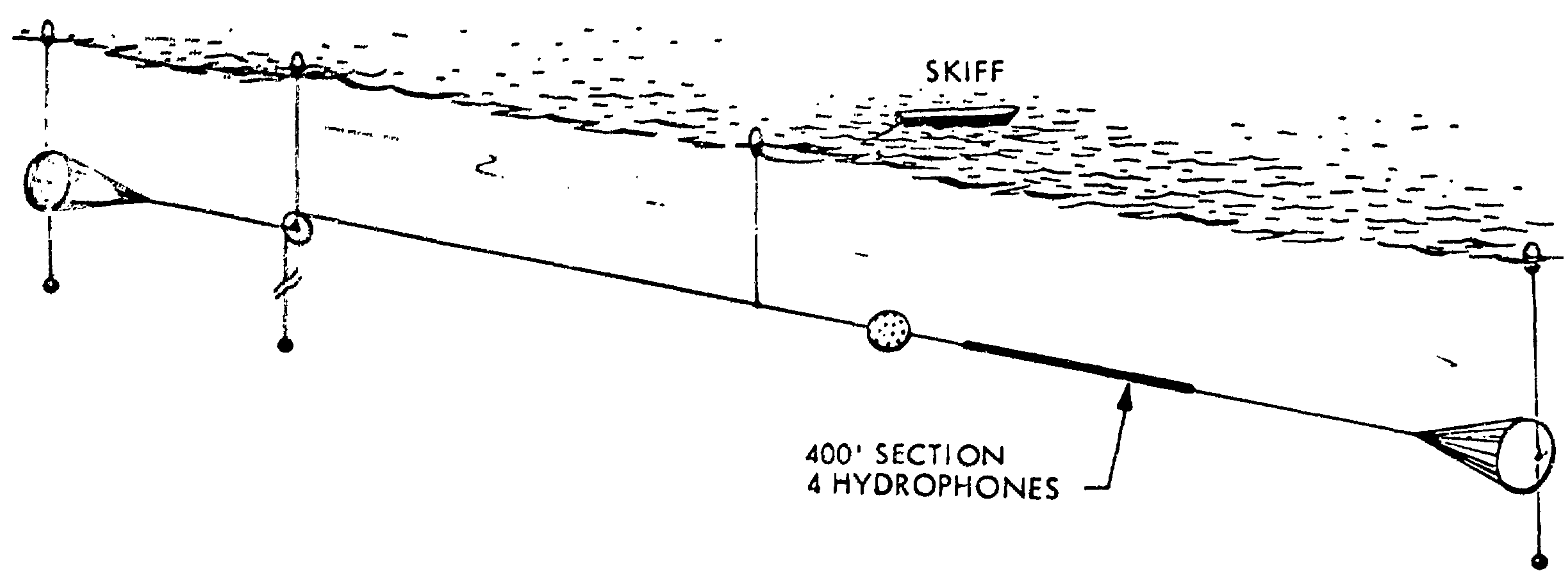


FIGURE 2-1

radiated by the R/V SWAN.

III TEST PROCEDURES

The objective of the DELTA/SCARF noise measurement test is to verify the very low frequency acoustic capability of the DELTA system by means of a side by side comparison with the Santa Cruz Island Acoustic Range Facility (SCARF) acoustic data.

To accomplish this objective the DELTA system was shipped by truck from San Diego to Santa Barbara and loaded aboard the R/V SWAN on 5 August 1975.

It had been planned to deploy the DELTA System within one mile of the noise measurement string, but due to the measured current of 0.6 knots at a depth of 500 ft, SCARF directed a separation of 3 miles to keep the DELTA System clear of their noise measurement string. Figure 3-1, "DELTA/SCARF TEST", shows the relative position of the DELTA System and the noise measurement string. Depths are indicated in fathoms. The instrumentation skiff was manned for this test for the purpose of adjusting gain settings to the amplifiers.

The DELTA System was deployed at 1420. Acoustic data was taken from 1515 to 1612 with SCARF recording the output of the noise measurement string during the same period.

The R/V SWAN moored overnight south of Santa Cruz Island and returned to Santa Barbara on the high tide at 1030 on 7 August 1975.

The data was reduced on a SD330 spectrum analyzer using a frequency range of 0 to 100 Hz. The frequency bins were 0.4 Hz apart. Due to the window used, each bin was 0.6 Hz wide. The number of values used in each average was 64, so the integration time was 64/0.4 = 160 sec.

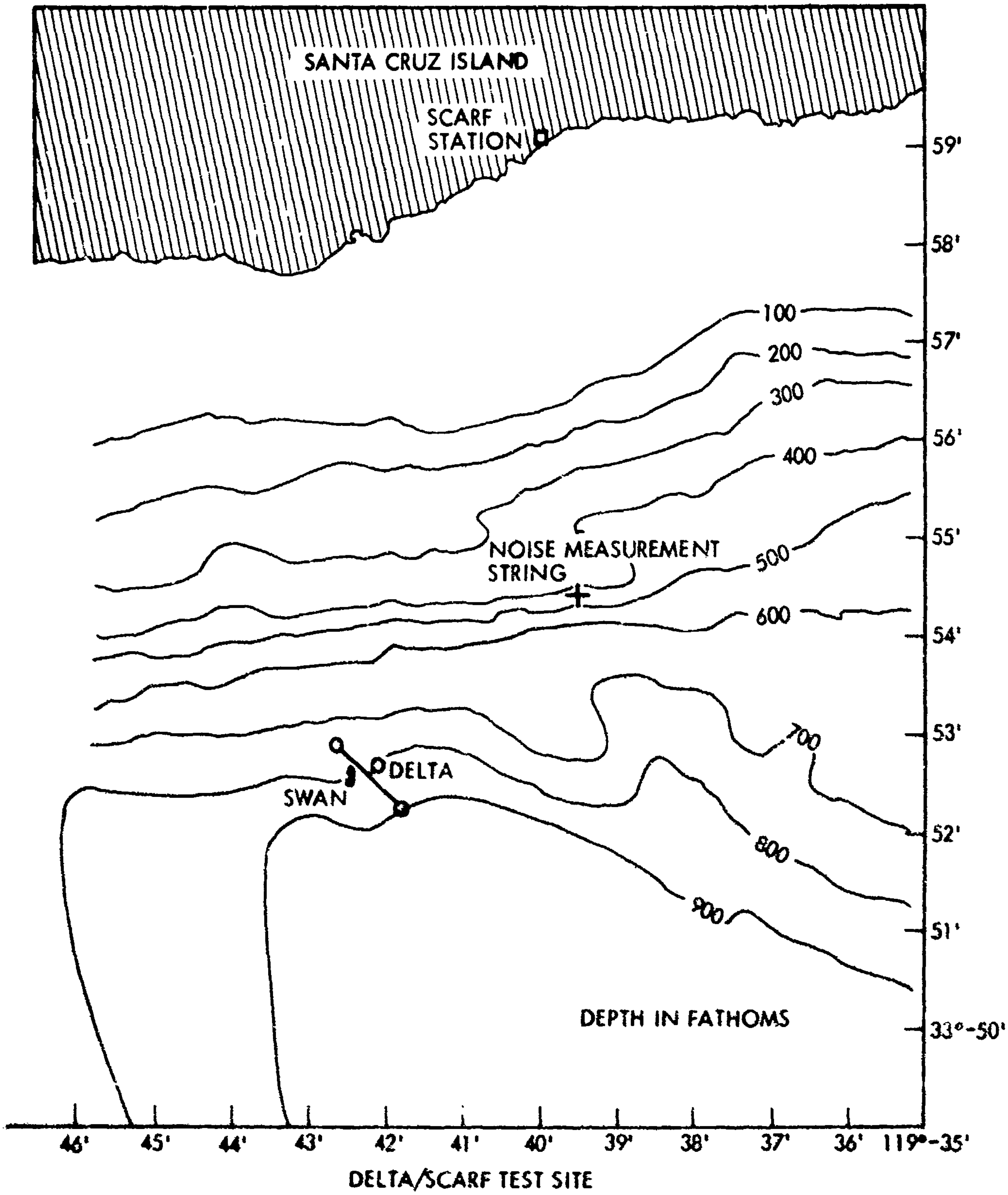

SANTA CRUZ ISLAND
SCARF
STATION
59'
58'
100
57'
200
300
56'
400
NOISE MEASUREMENT
STRING
55'
500
600
54'
53'
700
DELTA
SWAN
52'
800
900
51'
DEPTH IN FATHOMS
33°-50'
46'
45'
44'
43'
42'
41'
40'
39'
38'
37'
36'
119°-35'
DELTA/SCARF TEST SITE

FIGURE 3-1

Calibration of the DELTA data was accomplished by: 1.) Correcting the levels from the SD330 to 1 Hz equivalent; 2.) Subtracting the amplification of the amplifiers in the circuit; 3.) Subtracting the hydrophone sensitivity (-95.5 dB), and 4.) Adding the attenuation values of the high-pass filters used (there were three RC filters used with poles at 5 Hz, 5 Hz, and 2 Hz).

Calibration of the SCARF data followed a different procedure. Here a PRN (pseudo-random noise) was fed into the pre-amps at a level substantially above the hydrophone voltages (at most frequencies). The levels of the PRN voltages in selected 1 Hz bands are shown in Table 3.1. The hydrophone sensitivities are shown in Table 3.2. From this the equivalent acoustic sound pressure level can be calculated.

For example, at the output of the 600 ft sensor, at 25 Hz, a voltage of -85.4 dB re 1 volt was injected. Since the sensitivity of the sensor, from Table 3.2, was -81.8 dB, this corresponded to a received pressure of -3.6 dB re 1 ubar .

Note that all values below 20 Hz are extrapolated.

The system outputs were recorded when the PRN signal was present. During the analysis these recordings were used to provide a calibration which did not depend on individual component values of the system. A plot of the PRN noise as seen in the SD330 output is shown in Figure 3-2. The curve is assumed to represent the -3.6 dB re 1 ubar level.

It is possible that at the lowest frequencies the hydrophone voltages may have been strong enough to contribute significantly to the PRN level. If this happened, it would have caused an error in the generation of plots (Figures 4-5 to 4-8) at those frequencies. The actual values would have been higher than the plots shown.

PRN CALIBRATION (WITH HYDROPHONE)

Preamp Input Injection Level (dB V in 1 Hz Band

Freq.	S/N1	S/N2	S/N3	S/N4	S/N5	S/N6	S/N7	S/N8	S/N9	S/N10	S/N11
10*	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.9	-84.7	-84.2
12.5*	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.9	-84.7	-84.2
16*	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.[illegible]	-84.7	-84.2
20*	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.9	-84.7	-84.2
25	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.9	-84.7	-84.2
31.5	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.9	-84.7	-84.2
40	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.9	-84.7	-84.2
50	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.9	-84.7	-84.2
63	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.9	-84.7	-84.2
80	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.9	-84.7	-84.2
100	-85.5	-84.1	-85.4	-85.4	-84.7	-85.1	-85.5	-84.8	-84.[illegible]	-84.7	-84.2
125	-85.7	-84.4	-85.7	-85.8	-85.0	-85.4	-86.0	-85.0	[illegible]	-85.1	-84.4
160	-86.1	-84.7	-86.1	-86.2	-85.5	-85.9	-86.4	-85.3	-85.5	-85.4	-84.9
200	-86.8	-85.2	-86.7	-86.8	-85.0	-86.6	-87.1	-85.8	-86.2	-86.1	-85.6
250	-87.7	-86.1	-87.4	-87.7	-86.9	-87.5	-87.4	-86.4	-87.0	-87.0	-86.3
315	-88.5	-86.9	-88.4	-88.6	-87.9	-88.3	-88.4	-87.5	-88.0	-88.0	-87.2
400	-89.3	-88.1	-89.7	-89.8	-89.0	-89.6	-90.0	-88.9	-89.1	-89.1	-88.4
500	-90.7	-89.3	-91.0	-91.1	-90.3	-90.9	-91.4	-90.1	-90.4	-90.4	-89.8
630	-92.1	-90.8	-92.4	-92.5	-91.7	-92.4	-92.5	-91.6	-91.8	-91.9	-91.2
800	-93.6	-92.4	-94.2	-94.2	-93.6	-94.1	-94.6	-93.3	-93.5	-93.4	-92.8
1K	-95.1	-94.3	-95.9	-96.0	-95.0	-95.8	-96.4	-95.1	-95.2	-95.1	-94.3
1.2K	-97.1	-96.1	-97.7	-97.9	-96.7	-97.6	-98.1	-97.1	-97.2	-96.8	-96.1
1.6K	-99.1	-98.1	-99.7	-99.9	-98.7	-99.5	-100.1	-99.1	-99.2	-98.8	-98.1
2K	-101.1	-100.1	-101.7	-101.9	-100.7	-101.4	-102.1	-101.1	-101.2	-100.8	-100.1
2.5K	-103.1	-102.1	-103.7	-103.9	-102.7	-103.3	-104.1	-103.1	-103.2	-102.8	-102.1
3.1K	-105.1	-104.1	-105.7	-105.9	-104.7	-105.3	-106.1	-105.1	-105.2	-104.8	-104.1
4K	-107.1	-106.1	-107.7	-107.9	-106.7	-107.3	-108.1	-107.1	-107.2	-106.8	-106.1
5K	-109.1	-108.1	-109.7	-109.9	-108.7	-109.3	-110.1	-109.1	-109.2	-108.8	-108.1
6.3K	-111.1	-110.2	-111.7	-111.9	-110.7	-111.2	-112.1	-111.1	-111.2	-110.8	-110.1
8K	-113.1	-112.3	-113.7	-113.9	-112.7	-113.2	-114.1	-113.1	-113.2	-112.8	-112.1
10K	-115.1	-114.4	-115.7	-115.9	-114.7	-115.2	-116.1	-115.1	-115.2	-114.8	-114.1
12.5K	-117.[illegible]	-116.4	-117.7	-117.9	-116.7	-117.2	-118.1	-117.1	-117.2	-116.8	-116.1
16K	-119.1	-118.6	-119.7	-119.9	-118.7	-119.2	-120.1	-119.1	-119.2	-118.8	-118.1
20K	-120.5	-119.8	-121.1	-121.3	[illegible]	-120.5	[illegible]	-120.[illegible]	-120.0	-120.2	-119.5
25K	-121.0	-120.3	-121.6	-121.8	[illegible]	-121.2	[illegible]	-121.0	[illegible]	-120.7	-120.0
31.5K	-120.0	-119.3	-120.6	[illegible]	[illegible]	-120.0	-121.0	-120.0	[illegible]	-119.7	-119.0
40K	-129.0	-128.3	-129.6	-129.8	[illegible]	-129.0	-130.0	-129.0	-129.[illegible]	-128.7	-128.0

* Extrapolated below 25 Hz

Note: These data represent effective noise levels at input to preamplifier as seen through quadrasphere transducer.

Table 3-1

Summary of Noise Measurement Hydrophone Calibration at TRANSDEC, March 17, 18, 1975 (Corrected for Test Cable Capacitance)

Freq. (Hz)	Hydrophone Sensitivity (dBv//Microbar)									
	1	2	3	4	5	6	7	8	9	11	12
10*	-81.5	-81.6	-81.7	-81.7	-82.0	-81.6	-81.6	-81.7	-82.0	-82.0	-81.
12.5*	-81.5	-81.6	-81.7	-81.7	-82.0	-81.6	-81.6	-81.7	-82.0	-82.0	-81.
16*	-81.5	-81.6	-81.7	-81.7	-82.0	-81.6	-81.6	-81.7	-82.0	-82.0	-81.
20	-81.6	-81.7	-81.7	-82.0	-82.5	-81.6	-82.1	-82.0	-82.1	-82.5	-81.
25	-81.2	-81.5	-81.8	-81.7	-81.9	-81.5	-81.5	-81.7	-81.8	-81.9	-81.
31.5	-81.3	-81.6	-81.8	-81.7	-81.9	-81.5	-81.5	-81.6	-82.0	-81.8	-81.
40	-81.5	-81.6	-81.7	-81.7	-82.0	-81.6	-81.7	-81.6	-81.9	-81.8	-81.
50	-81.5	-81.7	-81.7	-81.6	-82.0	-81.5	-81.7	-81.7	-82.0	-81.9	-81.
63	-81.5	-81.7	-81.7	-81.7	-82.0	-81.6	-81.7	-81.7	-82.0	-81.9	-82.
80	-81.5	-81.8	-81.9	-81.8	-82.0	-81.6	-81.7	-81.7	-82.4	-82.0	-81.
100	-81.5	-81.8	-81.8	-81.9	-82.0	-81.7	-81.7	-81.7	-82.3	-82.0	-81.
125	-81.5	-82.0	-81.7	-82.0	-82.0	-81.7	-81.7	-81.7	-82.2	-81.9	-81.
160	-81.5	-81.8	-81.7	-82.1	-82.0	-81.5	-81.6	-81.7	-82.2	-81.8	-81.
200	-81.5	-81.9	-81.7	-82.3	-82.1	-81.7	-81.7	-81.5	-82.0	-81.8	-81.
250	-81.5	-82.2	-81.9	-82.3	-82.1	-81.5	-81.8	-81.6	-82.6	-81.8	-82.
315	-81.6	-82.1	-81.9	-82.1	-82.1	-81.7	-81.9	-82.7	-82.7	-81.8	-81.
400	-81.7	-82.3	-81.9	-82.0	-82.1	-81.7	-81.9	-81.7	-82.6	-81.9	-82.
500	-81.9	-82.4	-81.9	-82.3	-82.2	-81.9	-81.9	-81.7	-82.6	-81.8	-82.
630	-81.6	-82.4	-81.9	-82.0	-82.2	-81.7	-82.0	-81.7	-82.7	-81.8	-82.
800	-81.5	-82.3	-81.5	-81.8	-81.9	-81.6	-82.0	-81.7	-82.5	-81.7	-82.
1000	-81.5	-82.2	-81.3	-81.6	-81.8	-81.5	-81.7	-81.7	-82.2	-81.8	-81.
1250	-81.6	-81.9	-81.2	-81.5	-81.7	-81.5	-81.7	-81.6	-82.1	-81.7	-82.
1600	-81.6	-81.8	-81.6	-81.7	-81.9	-81.2	-81.7	-81.5	-81.9	-81.7	-81.
2000	-81.5	-81.8	-81.5	-81.7	-81.9	-81.7	-81.9	-81.7	-81.9	-81.9	-81.
2500	-81.5	-81.8	-81.7	-81.7	-81.9	-81.7	-81.6	-81.5	-82.3	-81.9	-81.
3150	-81.3	-81.7	-81.5	-81.7	-81.7	-81.8	-81.4	-81.5	-82.3	-81.7	-81.
4000	-81.3	-81.5	-81.7	-81.7	-81.8	-81.7	-81.7	-81.4	-82.4	-81.7	-82.
5000	-82.3	-82.4	-82.3	-82.4	-82.5	-82.7	-82.9	-82.0	-82.4	-82.7	-82.
6300	-82.9	-82.6	-82.7	-82.7	-82.7	-82.8	-82.9	-82.4	-82.7	-83.0	-82.
8000	-83.6	-82.9	-83.4	-83.4	-83.5	-83.5	-83.7	-82.9	-83.0	-83.5	-83
10000	-83.8	-83.4	-83.7	-83.7	-83.6	-83.7	-83.7	-83.2	-83.2	-83.7	-83
12500	-83.9	-83.6	-83.7	-83.7	-83.9	-83.8	-83.8	-83.6	-83.6	-83.8	-83.
16000	-84.6	-84.1	-84.4	-84.4	-84.0	-84.4	-84.3	-83.6	-83.7	-84.0	-83
20000	-84.3	-83.9	-84.5	-84.5	-84.0	-84.4	-84.3	-83.6	-83.3	-83.9	-83
25000	-83.6	-84.2	-84.7	-84.7	-84.4	-84.1	-84.1	-83.9	-83.9	-84.0	-83
31500	-81.6	-82.0	-82.0	-82.0	-82.0	-82.7	-82.7	-82.0	-81.9	-82.0	-81.
40000	-87.1	-86.2	-87.2	-87.0	-88.7	-88.6	-88.9	-87.0	-87.9	-88.0	-87

* Extrapolated below 20 Hz.

Table 3-2

SCARF ELECTRICAL CALIBRATION 0 – 100 Hz

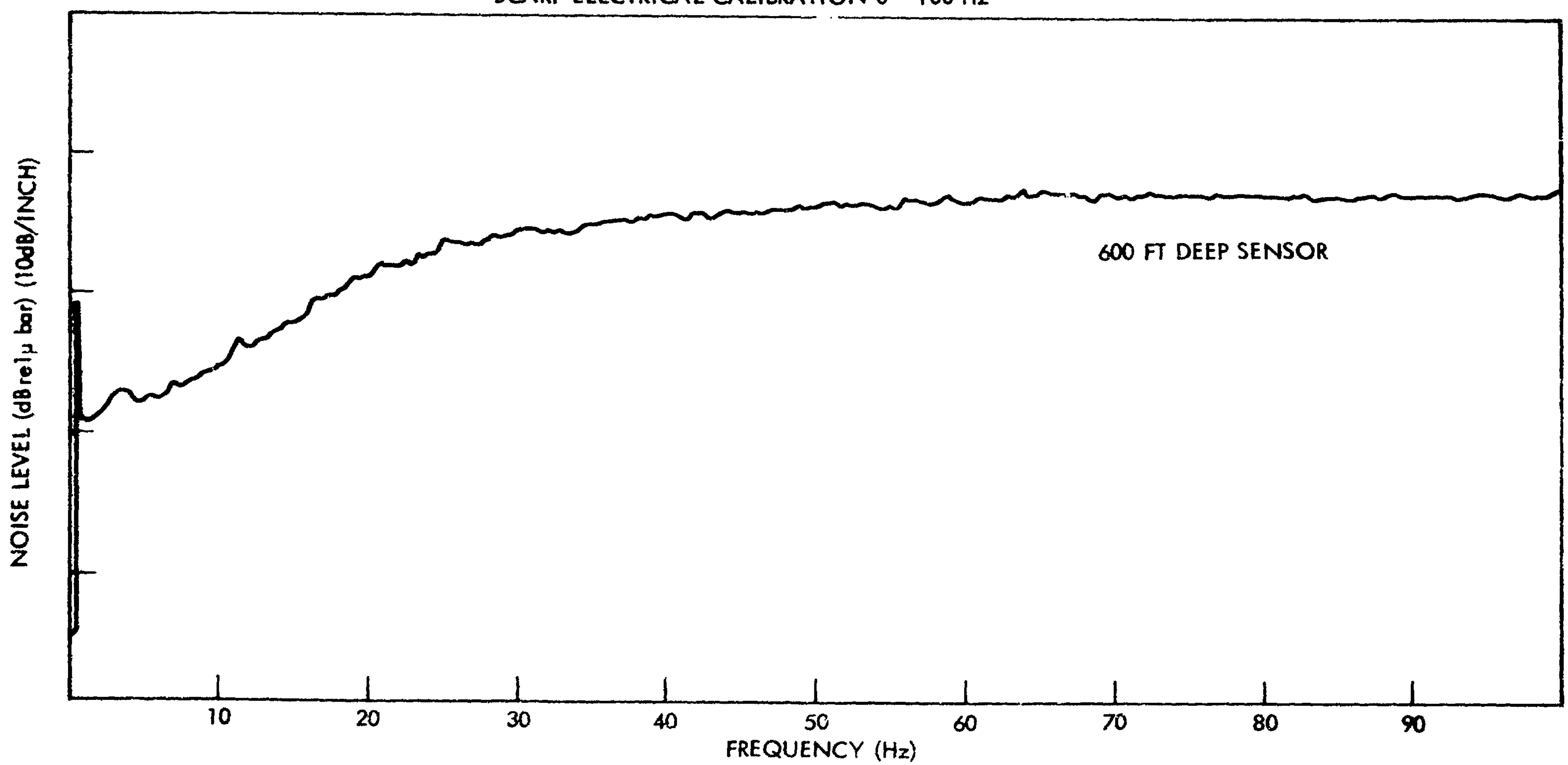


FIGURE 3-2

IV TEST RESULTS

The spectra of the sensor voltages are shown in Figures 4-1 to 4-8. Figures 4-1 to 4.4 show the spectra from the four elements of the DELTA array. Figures 4-5 to 4-8 show spectra from the SCARF noise measurement array. The data from the 600 ft SCARF sensor is most appropriate for comparison with the DELTA data, since the depths were nearly the same. Therefore, the 600 ft SCARF data has been plotted in Figures 4-1 to 4-4 for ease of comparison.

The data divides roughly into three frequency ranges: below 20 Hz, 20 Hz to 50 Hz, and above 50 Hz.

It should be remembered that calibration of the SCARF sensors is difficult below 20 Hz. The lowest frequency at which an actual calibration point exists is 20.0 Hz. Below this the calibration is an extrapolation. Subject to such uncertainties, the DELTA sensors appear to have a noise floor 5 to 10 dB below the SCARF sensors. (With the partial exception of Channel 1.) Channel 1 often performs slightly worse than the other channels, probably because of the vibration attenuation properties of the array walls.)

Below 20 Hz, both DELTA and SCARF are probably limited by self noise. Above 50 Hz, both DELTA and SCARF are probably limited by ocean ambient noise. Therefore, we might expect the 20 Hz to 50 Hz region to be a transition region. This seems to be the case. The acoustic performance of the two sensors is comparable, although they are clearly hearing different things.

Above 50 Hz, both arrays are probably hearing essentially ocean noise. However in the case of DELTA, the noise is probably coming from the R/V SWAN. During the test, the R/V SWAN was generally between 6,000 yd. and 7000 yd. from the SCARF sensors, but it was only 500 yd. to 1500 yd. from

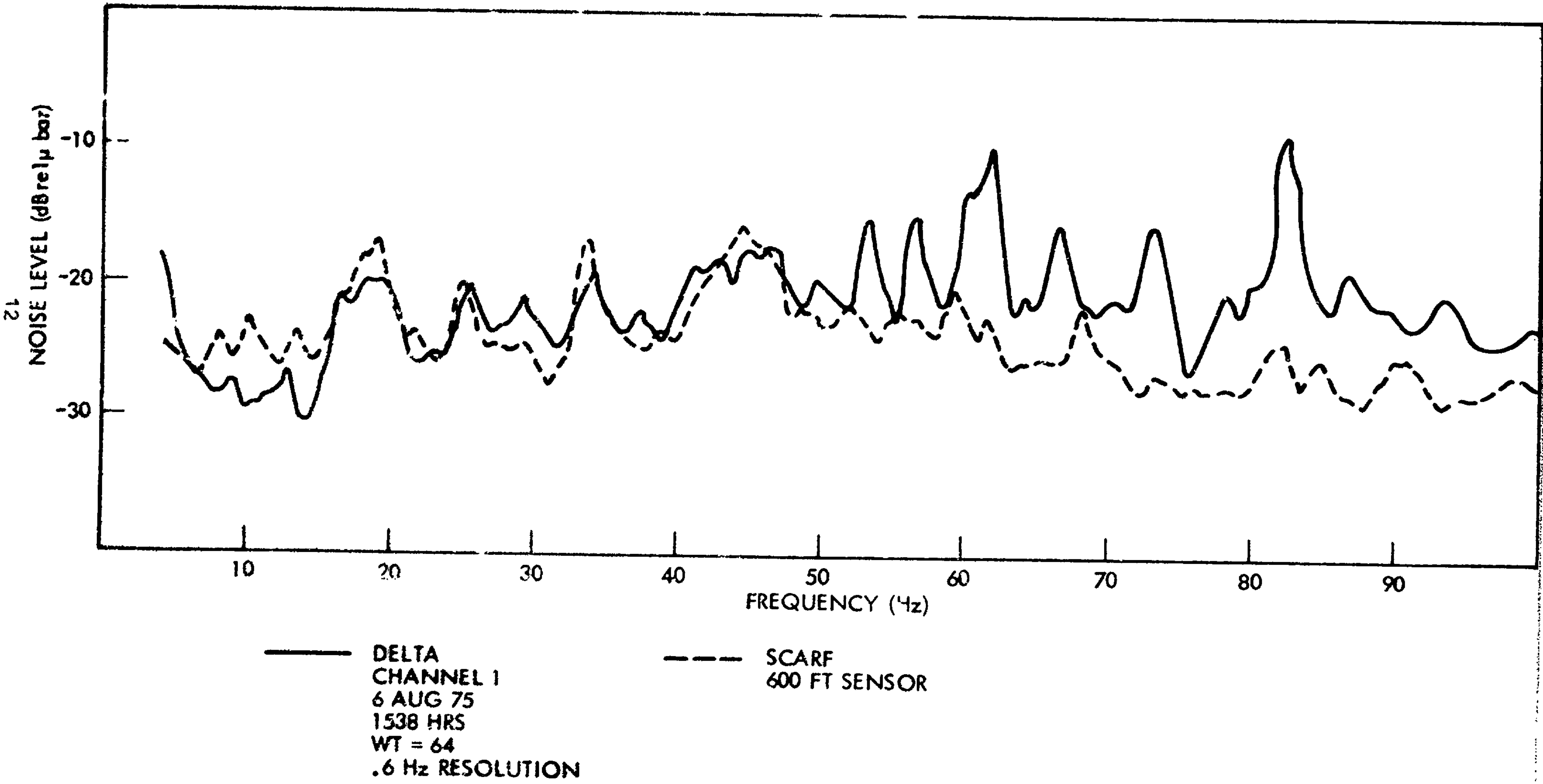

NOISE LEVEL (dB re 1 μ bar)
-10
-20
-30
10
20
30
40
50
60
70
80
90
FREQUENCY (Hz)
DELTA
CHANNEL 1
6 AUG 75
1538 HRS
WT = 64
.6 Hz RESOLUTION
SCARF
600 FT SENSOR

FIGURE 4-1

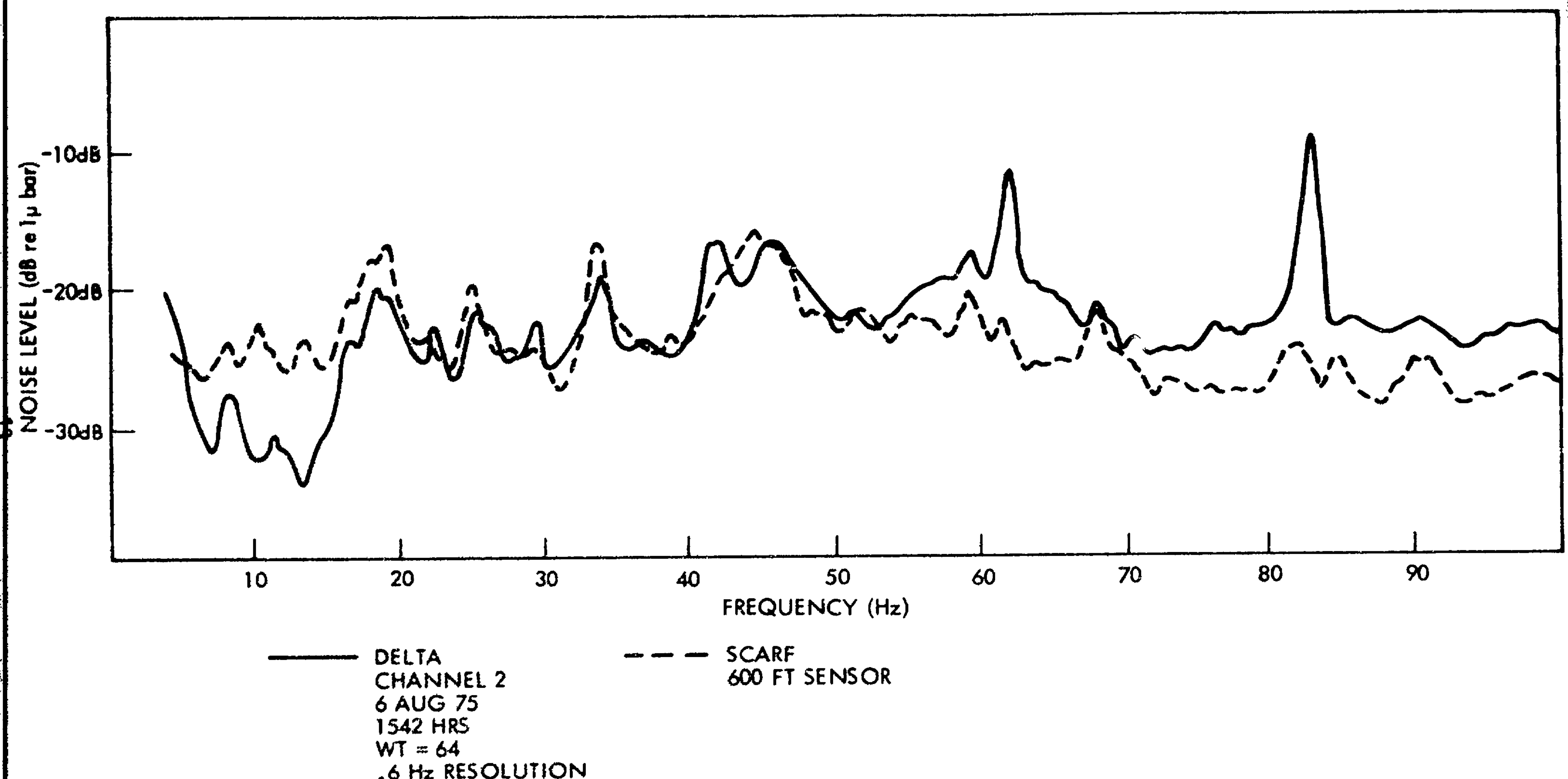

NOISE LEVEL (dB re 1μ bar)
-10dB
-20dB
-30dB
10
20
30
40
50
60
70
80
90
FREQUENCY (Hz)
DELTA
CHANNEL 2
6 AUG 75
1542 HRS
WT = 64
.6 Hz RESOLUTION
SCARF
600 FT SENSOR

FIGURE 4-2

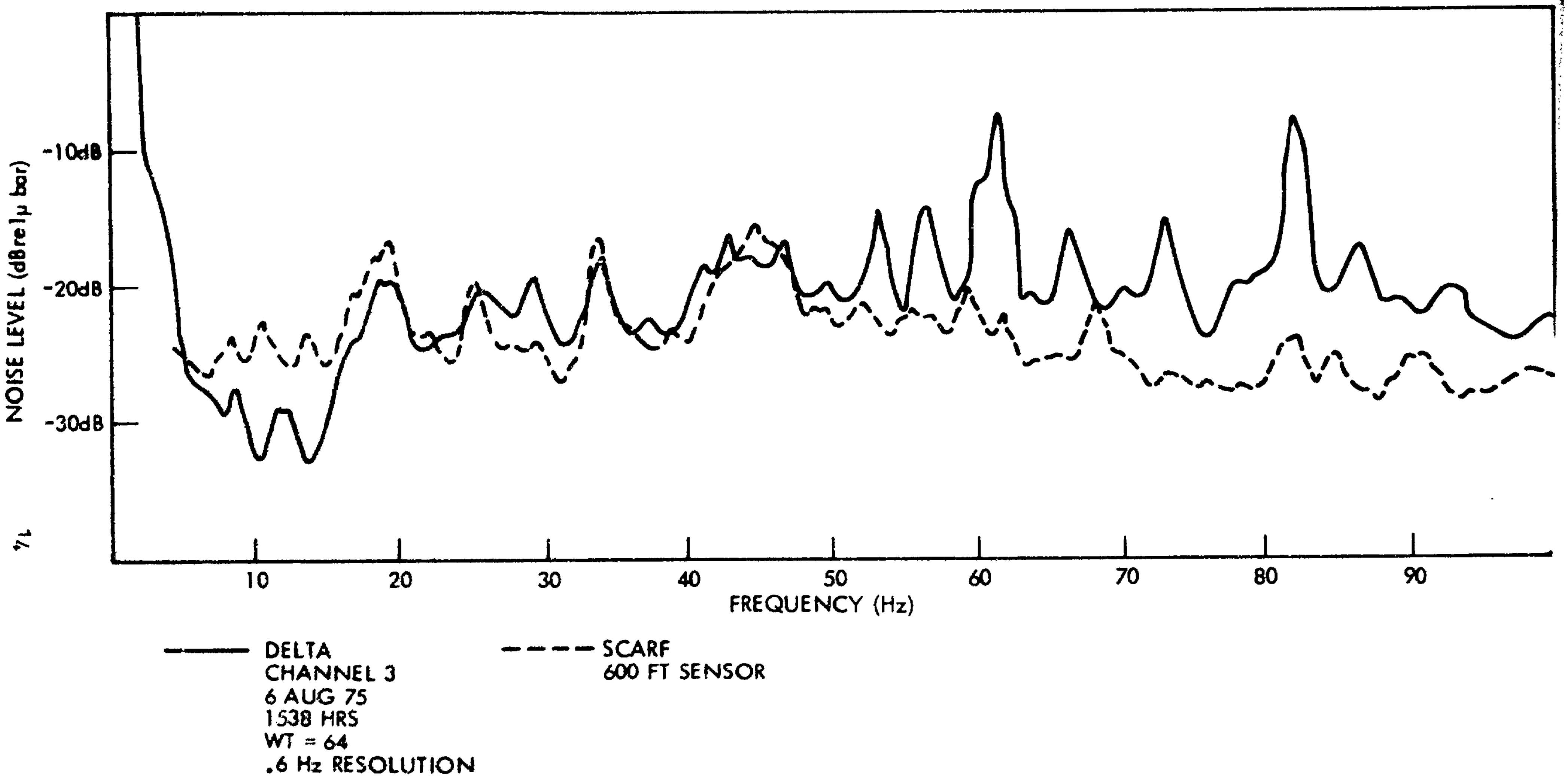

NOISE LEVEL (dBre1µ bar)
-10dB
-20dB
-30dB
10
20
30
40
50
60
70
80
90
FREQUENCY (Hz)
DELTA
CHANNEL 3
6 AUG 75
1538 HRS
WT = 64
.6 Hz RESOLUTION
SCARF
600 FT SENSOR

FIGURE 4-3

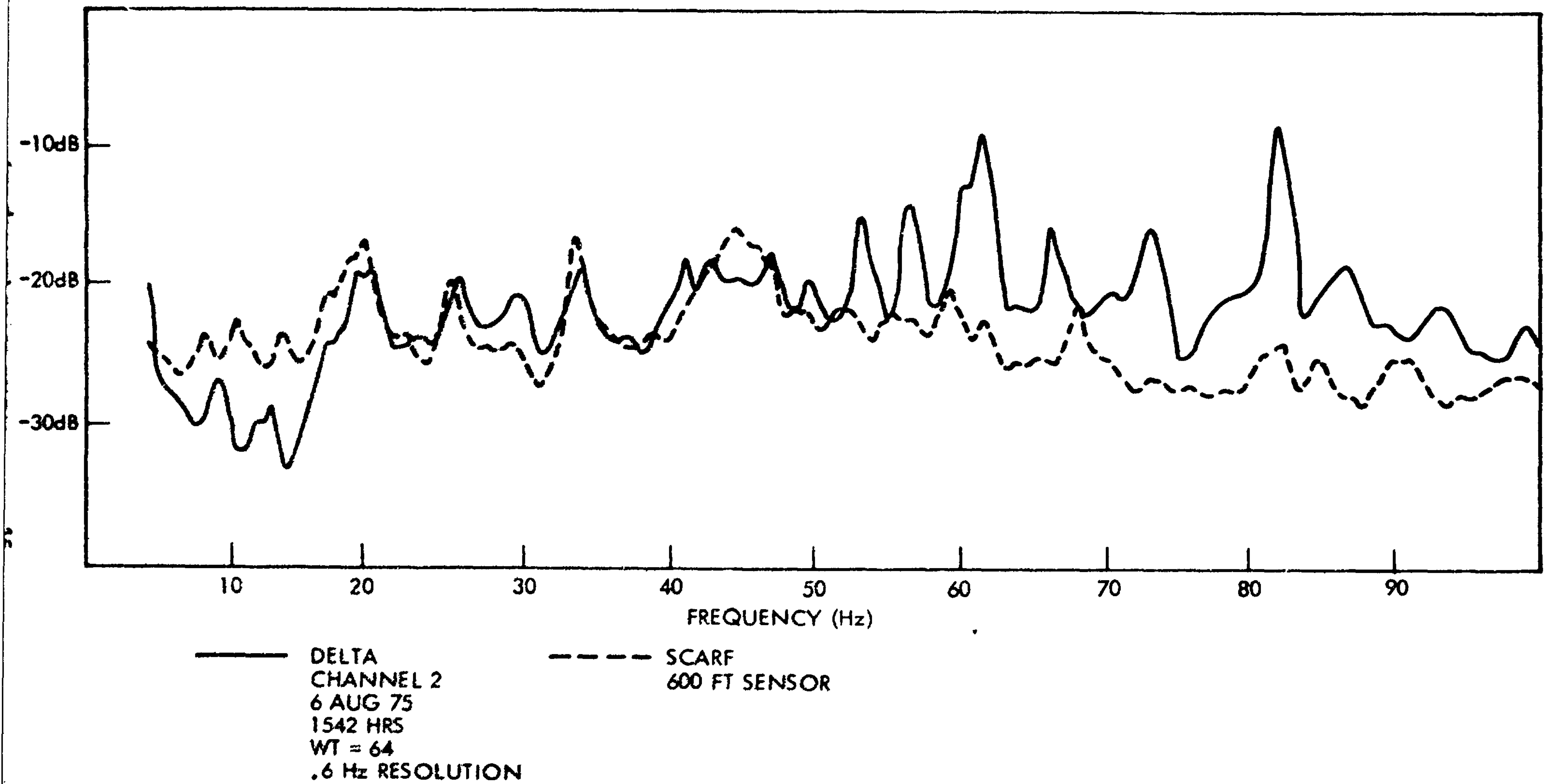

-10dB
-20dB
-30dB
10
20
30
40
50
60
70
80
90
FREQUENCY (Hz)
DELTA
CHANNEL 2
6 AUG 75
1542 HRS
WT = 64
.6 Hz RESOLUTION
SCARF
600 FT SENSOR

FIGURE 4-4

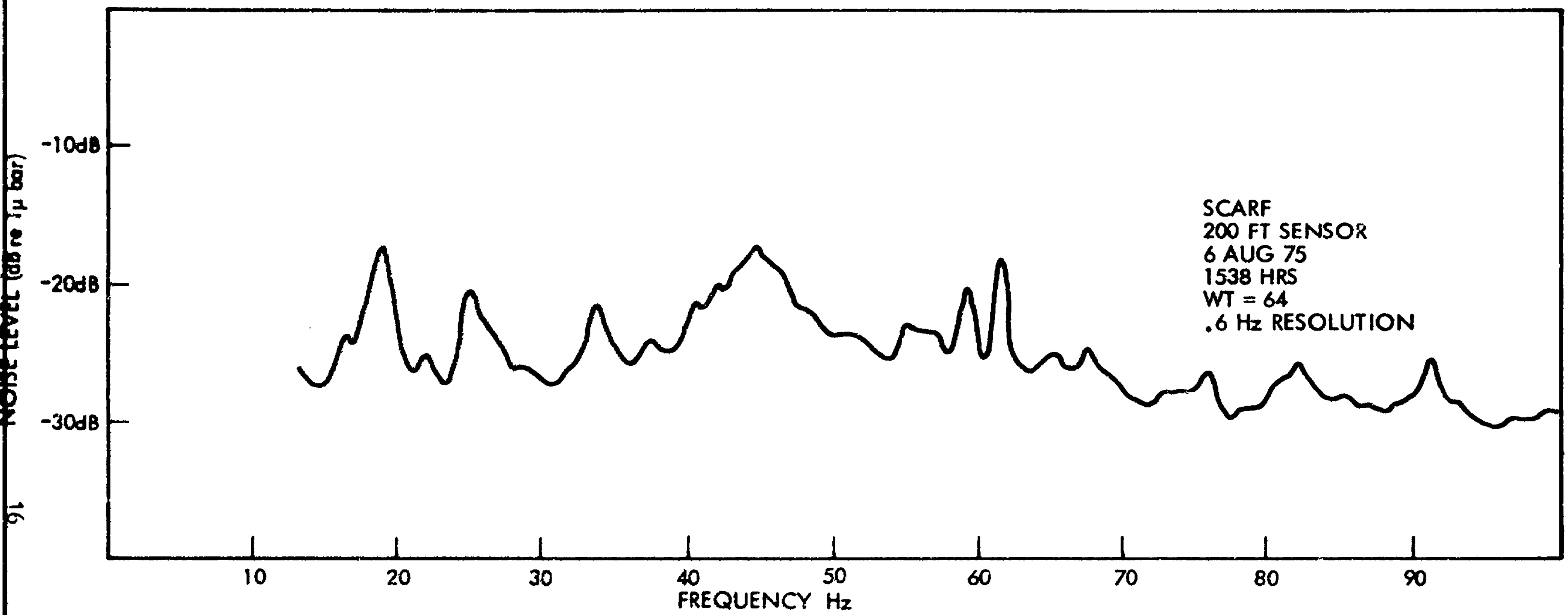

NOISE LEVEL (dB re 1 μ bar)
-10dB
-20dB
-30dB
SCARF
200 FT SENSOR
6 AUG 75
1538 HRS
WT = 64
.6 Hz RESOLUTION
10
20
30
40
50
60
70
80
90
FREQUENCY Hz

FIGURE 4-5

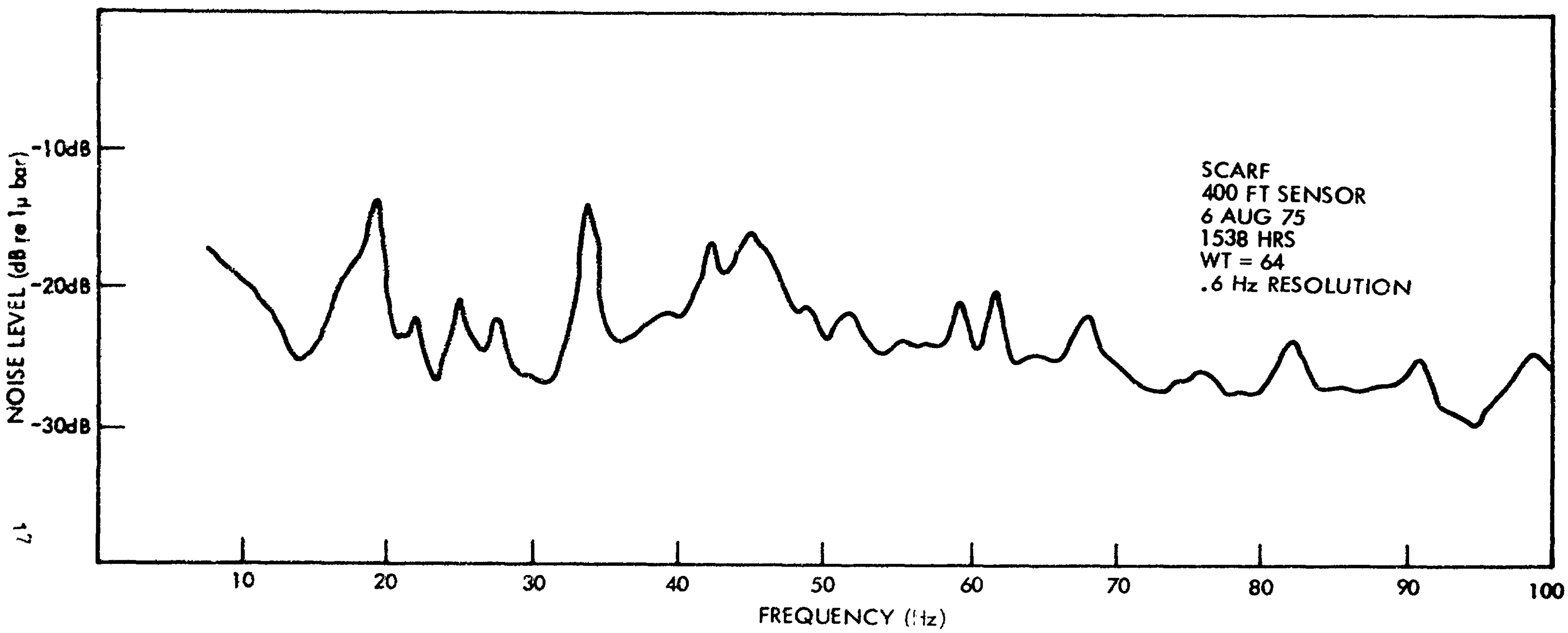
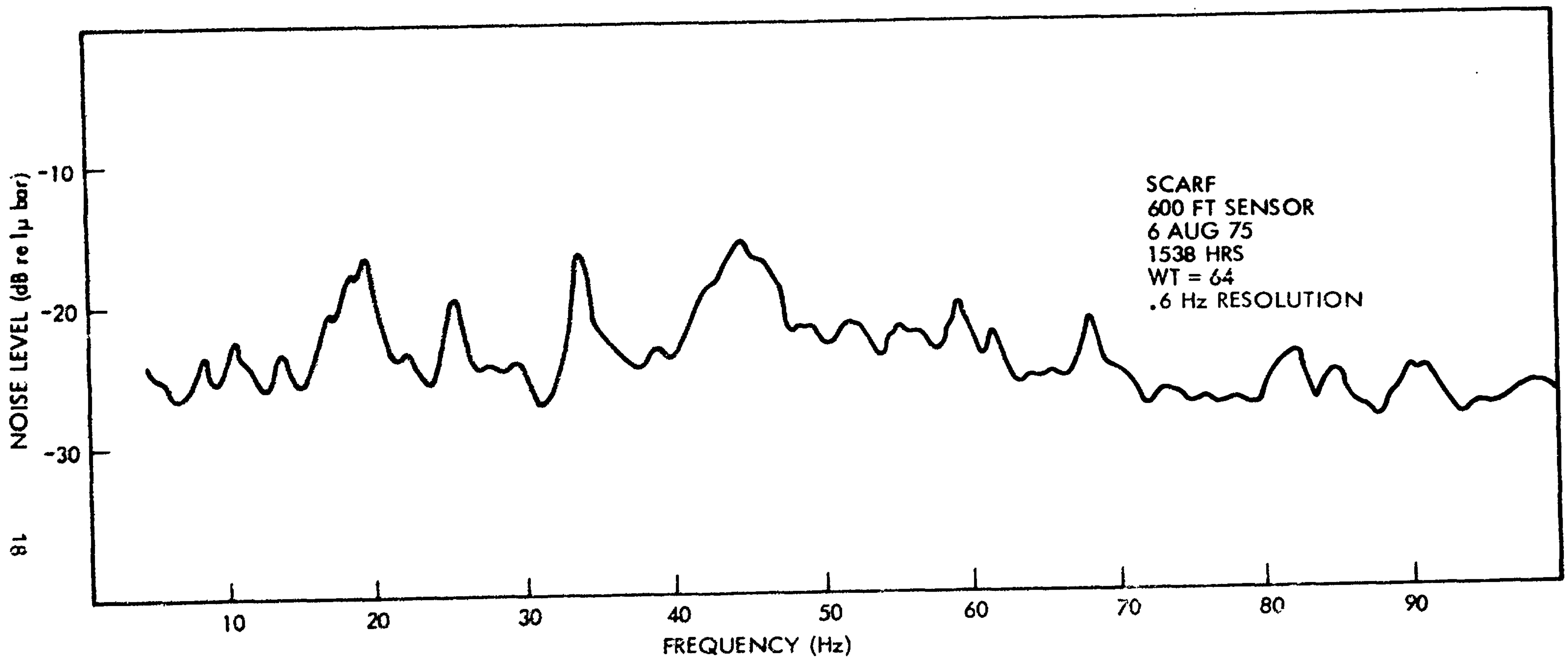

NOISE LEVEL (dB re 1μ bar)
-10dB
-20dB
-30dB
SCARF
400 FT SENSOR
6 AUG 75
1538 HRS
WT = 64
.6 Hz RESOLUTION
10
20
30
40
50
60
70
80
90
100
FREQUENCY (Hz)

FIGURE 4-6


SCARF
600 FT SENSOR
6 AUG 75
1538 HRS
WT = 64
.6 Hz RESOLUTION
NOISE LEVEL (dB re 1μ bar)
-10
-20
-30
10
20
30
40
50
60
70
80
90
FREQUENCY (Hz)

RE 4-7

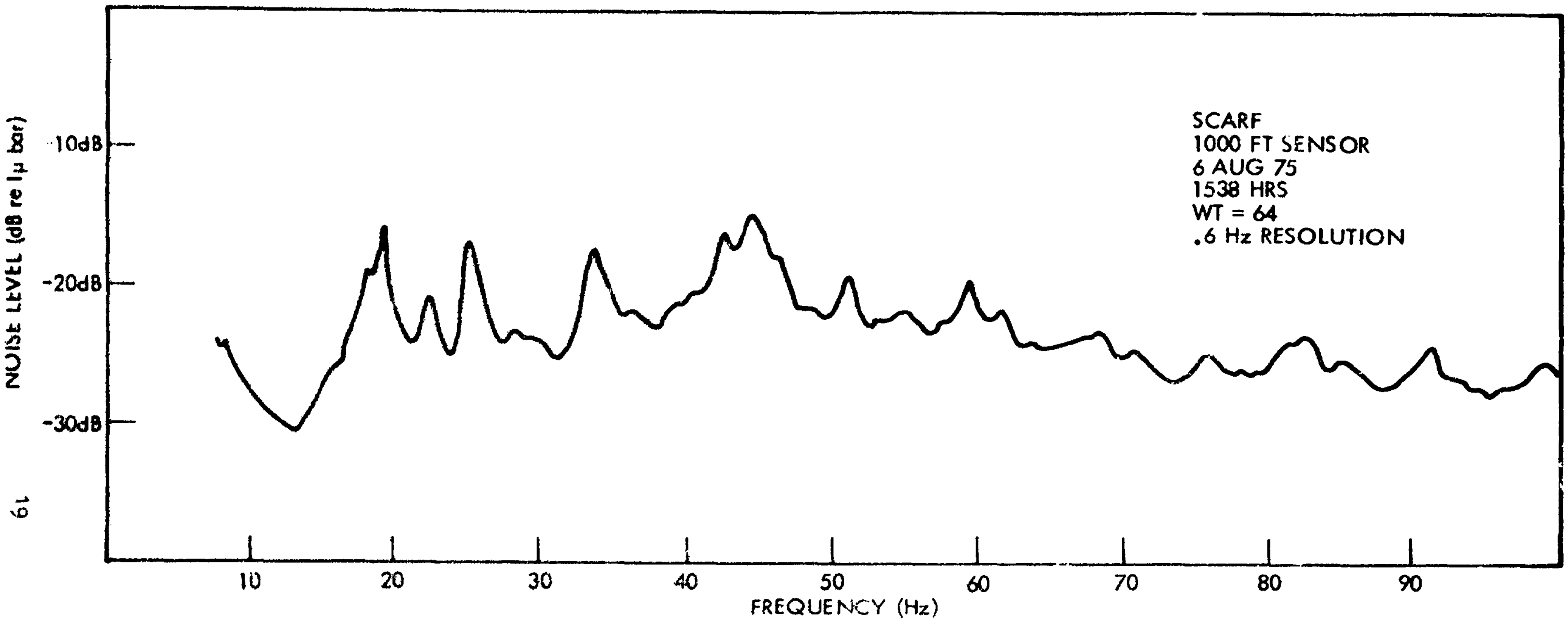

SCARF
1000 FT SENSOR
6 AUG 75
1538 HRS
WT = 64
.6 Hz RESOLUTION
NOISE LEVEL (dB re 1µ bar)
-10dB
-20dB
-30dB
10
20
30
40
50
60
70
80
90
FREQUENCY (Hz)

FIGURE 4-8

the DELTA sensors. The result clearly shows up in the spectral curves.

The principal test objective was to evaluate the self noise of the DELTA sensors in the 5 Hz to 15 Hz region. The curves show that this was generally between -24 dB and -34 dB re 1 ubar/Hz. The agreement with the SCARF data in the 20 Hz to 30 Hz region (where surface decoupling effects tend to begin removing ship noise) supports this conclusion.

V CONCLUSIONS

The data is consistent with what would have been expected from a fairly simple physical model. To review, the model is as follows:

a) Below 20 Hz, both DELTA and SCARF are probably self noise limited. Due to the reduction of relative motion between the array and the ocean currents, the DELTA sensors are several dB quieter.

b) Above 50 Hz, ship noise dominates the spectra. In the case of DELTA, the ship is the R/V SWAN. In the case of SCARF, the noise from the R/V SWAN was less severe, and more distant ships were represented.

c) As frequency decreases below 50 Hz, the ships radiate noise progressively less effectively, due to their small size and proximity to the ocean surface. Thus a transition from ship noise to self noise occurs between 20 Hz and 50 Hz.

The DELTA array, therefore, performed about as expected.

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Report Number	Personal Author	Title	Publication Source (Originator)	Pub. Date	Current Availability	Class.
55	Weinstein, M. S., et al.	SUS QUALITY ASSESSMENT, SQUARE DEAL	Undersea Systems, Inc.	750207	ADA007559; ND	U
BKD2380	Unavailable	WESTLANT 74 PHASE 1 DATA SUMMARY (U)	B-K Dyanmics, Inc.	750301	NS; ND	U
TM-SA23-C44-75	Wilcox, J. D.	MOTION MODEL VALIDATION FROM LRAPP ATLANTIC TEST BED DATA	Naval Underwater Systems Center	750317	ND	U
RAFF7412; 74-482	Scheu, J. E.	SQUARE DEAL SHIPPING DENSITIES (U)	Raff Associates, Inc.	750401	ADC003198; NS; ND	U
PSI TR-004018	Barnes, A. E., et al.	ON THE ESTIMATION OF SHIPPING DENSITIES FROM OBSERVED DATA	Planning Systems Inc.	750401	ND AD096582	U
NUSC TD No.4937	LaPlante, R. F., et al.	THE MOORED ACOUSTIC BUOY SYSTEM (MABS)	Naval Underwater Systems Center	750404	ADB003783; ND	U
USI 460-1-75	Weinstein, M. S., et al.	SUS SIGNAL DATA PROCESSING (U) INVESTIGATIONS CONDUCTED UNDER THE DIAGNOSTIC PLAN FOR CHURCH ANCHOR AND SQUARE DEAL SHOT DATA (U)	Underwater Systems, Inc.	750414	ADC002353; ND	U
Unavailable	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Applied Research Laboratories	750618	ADA011836	U
Unavailable	Edelblute, D. J.	OCEANOGRAPHIC MEASUREMENT SYSTEM TEST AT SANTA CRUZ ACOUSTIC RANGE FACILITY (SCARF)	Lockheed Missiles and Space Co., Inc.	751015	ADB007190	U
Unavailable	Unavailable	SUS SOURCE LEVEL COMMITTEE REPORT	Underwater Systems, Inc.	751105	ADA019469	U
Unavailable	Hampton, L. D.	ACOUSTIC BOTTOM INTERACTION EXPERIMENT DESCRIPTION	University of Texas, Applied Research Laboratories	760102	ADA021330	U
PSI-TR-036030	Turk, L. A., et al.	CHURCH ANCHOR: AREA ASSESSMENT FOR TOWED ARRAYS (U)	Planning Systems Inc.	760301	ND	U
NUC TP 419	Wagstaff, R. A., et al.	HORIZONTAL DIRECTIONALITY OF AMBIENT SEA NOISE IN THE NORTH PACIFIC OCEAN (U)	Naval Undersea Center	760501	ADC007023; NS; ND	U
NRL-MR-3316	Young, A. M., et al.	AN ACOUSTIC MONITORING SYSTEMS FOR THE VIBROSEIS LOW-FREQUENCY UNDERWATER ACOUSTIC SOURCE	Naval Research Laboratory	760601	ADA028239; ND	U
ARL-TR-75-32	Ellis, G. E.	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Applied Research Laboratories	760705	ADA028084; ND	U
Unavailable	Unavailable	SUMMARY OF ENVIRONMENTAL ACOUSTIC DATA PROCESSING	University of Texas, Computer Science Division	761013	ADA032562	U
TTA83676285	Unavailable	ANALYSIS PLAN FOR NARROWBAND/ NARROWBEAM AMBIENT NOISE (U)	Tetra Tech, Inc.	761112	ADC008275; NS; ND	U
USI 564-1-77	Wallace, W. E., et al.	REPORT OF CW WORKSHOP. NORDA, BAY ST. LOUIS, MISS., 28-29 SEPT 1976	Underwater Systems, Inc.	770124	ND	U